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(54) Name of the Invention: SEMICONDUCTOR DEVICE

(57) (Summary)

(Purpose)

The purpose of this invention is to provide a bipolar transistor provided with an insulating gate which has a high voltage resistance and which makes it possible to increase the AD amount resistance while the breakdown voltage is maintained between the drain and the source.

## (Construction)

An extension drain region 12 of the second conductive type and a high-concentration source region 16 of the second conductive type are formed on the surface part of semiconductor substrate 11 of the first conductive type. On the surface part of this extension drain region 12 is formed a high-concentration drain region 13 of the second conductive type, and a drain adjacent region 14 of the first conductive type which has a high concentration is formed so that it is electrically connected to high-concentration drain region 13 and so as to surround said high-concentration region 13 of the second conductive type., while top region 15 of the first conductive type is formed electrically connected to semiconductor substrate 11 so as to surround drain adjacent region 14. The distance X1 between top region 15 and drain adjacent region 14 is a set distance which can be set for example to 10  $\mu\text{m}$  to increase the resistance value between top region 15 and drain adjacent region 14 above a predetermined value.

[see figure on the right]

- 10 L-JGBT (semiconductor device)
- 11 semiconductor device
- 12 extended drain region
- 13 high-concentration drain region
- 14 drain adjacent region
- 15 top region
- 16 high-concentration source region

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## (Scope of the Patent's Claims)

## (Claim 1)

A semiconductor device,

equipped with a semiconductor substrate of the first concentration type, an extended region of the second conductive type formed on the surface part of said semiconductor substrate, a high-concentration drain region of the second conductive type formed on the surface part of said extended drain region, a high-concentration source region of the second conductive type formed outside of said extended drain region on the surface part of said semiconductor substrate, a top region of the first conductive type which is electrically connected to said semiconductor substrate and which is formed in a region between said high-concentration source region and said high-concentration drain region on the surface part of said extended drain region,

and with a high-concentration drain adjoining region of the first conductive type which is electrically connected to said high-concentration drain region and formed in a region adjoining

said high-concentration drain region between said top region and said high-concentration drain on the surface part of said extended drain region,

characterized by the fact that the distance between said drain adjoining region and said top region is set to a predetermined distance above 4  $\mu$ , increasing by a predetermined value the resistance value in the region between said drain adjoining region and said top region in said extended drain region.

(Detailed Explanation of the Invention)

(0001)

(Sphere of Industrial Use)

This invention relates to a semiconductor device, such as a bipolar transistor provided with a highly voltage-resistant horizontal insulating gate.

(0002)

(Prior Art)

The following explanation of a conventional type of a semiconductor device is based on the highly resistant horizontal insulation gate type of bipolar transistor (hereinafter abbreviated to L-IGBT) which is shown in the inclosed figures.

(0003)

Figure 3 shows a profile view of L-IGBT 50 representing a semiconductor device according to prior art. As shown in Figure 3, extension drain region 52 of the second conductive part is formed on the surface part of semiconductor substrate 51 of the first conductive part and on the surface part of said extension drain region 52 is formed a high-concentration drain region 53 of the second conductive type. High-concentration drain region 54 is formed electrically connected to high-concentration drain region 53 so that this high-concentration region 54 surrounds high-concentration drain region 53. In addition, top region 55 of the first conductive type is formed so as to surround drain adjacent region 54 and high-concentration drain region 53 on the surface part of extension drain region 52. This top region 55 is electrically connected to semiconductor substrate 51. Moreover, high-concentration source region 56 of the second conductive part is formed on the top surface part of semiconductor substrate 51 and in the central part of said high-concentration source region 56 is formed a high-concentration source adjacent region 57, while a high-concentration channel stopper 58 of the first conductive type is formed so as to surround high-concentration source region 56. Further, on the surface of semiconductor substrate 51 is formed gate oxide film 60 reaching from drain adjacent region 54 to high-

concentration region 56, and drain electrode 61 which has the profile shape of letter T and which is electrically connected to drain adjacent region 54 and to high-concentration drain region 53.

Source electrode region 62 which again has the profile shape of letter T is formed electrically connected to source adjacent region 57 and to high-concentration source region 56, while gate electrode 63 is formed from a polycrystalline silicon film reaching from the end part of extension drain region 52 into the end part of high-concentration source region 56 in the inner part of gate oxide film 60, and a channel is formed below gate electrode 63 in the surface part of semiconductor substrate 51.

(0004)

(Task To Be Achieved By This Invention)

However, when the distance X2 between the drain adjacent region and the top region shown in Figure 3 is too short in the L-IGBT design of a semiconductor device according to prior art shown in Figure 3, it is known that the problem is that the breakdown voltage will be decreased between the drain and the source.

(0005)

Taking into account the above facts, it was determined that when the interval X2 between the top region and the drain region is set to 4  $\mu\text{m}$ , the result is that the breakdown voltage between the drain and the source will not be reduced.

(0006)

Incidentally, when an inductance load circuit is used, due to reversed electromotive force supplied for inductance during the gate-off time period, a large breakdown current will be flowing between the drain and source when the anode which is built in between the drain and the source reaches the breakdown status. Because of that, when the voltage drop below the high-concentration source region reaches approximately 0.7 V in a bipolar transistor comprising an extended drain region of the second conductive type and a semiconductor substrate of the first conductive type, as well as a high-concentration source region of the second conductive type, the immediate problem was that the temperature increase could result in a thermal failure of the component. The amount of energy consumed at this point by an L-IGBT component is called the AD resistance amount of an L-IGBT component.

(0007)

In view of the above described problems, the purpose of this invention is to provide a semiconductor device making it possible to increase the AD resistance amount while the breakdown voltage is maintained between the drain and the source.

(0008)

(Means To Solve Problems)

In order to achieve the above mentioned objective, the present invention uses a design wherein the resistance value is increased above a specified value in the region between the drain adjoining region and the top region of an extended drain region. Because this makes it possible to control the operation of a bipolar transistor comprising an extended drain region of the second type and a semiconductor substrate of the first type with a high-concentration source region of the second type, the AD resistance amount can be greatly increased by this design.

(0009)

Specifically, the resolution providing means according to the construction of this invention, whose subject is a semiconductor device such as an L-IGBT component, etc., comprises a construction equipped with a semiconductor substrate of the first conductive type, an extended drain region of the second conductive type formed in the surface part of said semiconductor substrate, a high-concentration drain region of the second conductive type formed in the surface part of said extended drain region, a high-concentration source region of the second conductive part formed outside of said extended drain region on the surface part of said semiconductor substrate, and a top region of the first conductive part which is electrically connected to said semiconductor substrate, formed in a region between the high-concentration source and the high-concentration drain region in the surface part of said extended drain region;

and with a high-concentration drain adjacent region of the first conductive type electrically connected to said high-concentration drain region and formed in the region adjoining the high concentration drain region between the top region and the high-concentration drain region;

wherein the distance of the space between said drain adjacent region and said top region is set to a specified distance above 4  $\mu\text{m}$ , increasing above a predetermined value the resistance value in the region between the drain adjacent region and the top region in said extended drain region.

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(0010)

(Operation)

According to the above described construction, the interval between the top region and the drain adjoining region is set to a predetermined distance above 4  $\mu\text{m}$ . This makes it possible to maintain the breakdown voltage without decreasing it between the drain and the source.

(0011)

In addition, the interval between the top region and the drain region is thus set to a specified distance increasing by a predetermined value the resistance value in the region between the drain adjacent region and the top region in the extended drain region. In this case, said specified value means the resistance value in the region between the drain region and the top region in the extended drain region when the interval between the drain adjacent region and the top region is 4  $\mu\text{m}$ .

(0012)

Because of that, when the semiconductor device of this invention is for example used in an inductance load circuit, even when the breakdown status of a diode built between the drain and the source occurs due to reversed electromotive force of inductance during the gate-off period, because there is a large resistance between the drain adjacent region and the top region in the extended drain region, the breakdown current flowing below the high-concentration source region is reduced and a current corresponding to the reduced portion of the breakdown current will be flowing from the surface part of the semiconductor substrate to its reverse part.

(0013)

Because this makes it possible to reduce the breakdown electric current flowing below the high-concentration source region, this in turn makes it possible to suppress to a low level the voltage drop below the high-concentration source region.

(0014)

Accordingly, since this design makes it possible to control the operation of a bipolar transistor comprising an extended drain region of the second conductive type and a semiconductor substrate of the first conductive type with a high-concentration source region of the second conductive part, the AD resistance amount can be greatly increased by this.

(0015)

The following is an explanation of an embodiment of this invention which is based on the enclosed figures.

(0016)

Figure 1 shows a profile view indicate L-IGBT 10 representing a semiconductor device according to an embodiment of this invention. As shown in Figure 1, an island-shaped extended drain region 12 of the second conductive type is formed on the surface part of semiconductor device 11 of the first conductive type, and on the surface part of this extended drain region 12 are

formed a high-concentration drain region 13 and a high-concentration drain adjoining region 14 of the first conductive type so as to surround the high-concentration drain region 13 in the adjoining region. This drain adjoining region 14 is electrically connected to high-concentration drain region 13.

In addition, top region 15 of the first conductive part is formed so as surround high-concentration drain region 13 and drain adjoining region 14 in the extended part. The distance X1 between drain adjoining region 14 and top region 14 is a predetermined distance above 4  $\mu\text{m}$  by which the resistance value is increased in the region between drain adjoining region 14 and top region 15 in the extended drain region 14, and it can be set for instance to 10  $\mu\text{m}$ .

(0017)

Further, a high-concentration source region 16 of the second conductive type is formed outside of the extended drain region 12 in the surface part of semiconductor substrate 11, a high-concentration source adjoining region 17 of the first conductive type is formed in the central part of this high-concentration source region 16, and a high-concentration channel stopper 18 of the first conductive type is formed so as to surround high-concentration source region 16 outside of the extended drain region 12 on the surface part of semiconductor substrate 11.

(0018)

Furthermore, a gate oxide film 20 reaching from drain adjoining region 14 to high-concentration source region 16 is formed on the surface of semiconductor substrate 11, and a high-concentration source adjoining region 17 of the first conductive type is formed in the central part of this high-concentration source region 16, while high-concentration channel stopper 18 of the first conductive type is formed so as to surround high-concentration source region 16 outside of the extended drain region 12 on the surface part of semiconductor 11.

Also, the gate oxide film 20 which reaches from drain adjoining region 14 to high-concentration source region 16 is formed on the surface of semiconductor substrate 11 drain electrode 21 which is formed with the profile shape of letter T so that it is electrically connected to drain adjoining electrode 14 and to high-concentration drain region 14, source electrode 22 is formed with the profile shape of letter T so that it is electrically connected to source adjoining region 17 and high-concentration source region 16, and gate electrode 23 which is made from a polycrystalline silicon film is formed so that it reaches from the end part of extended drain region 12 to the end part of high-concentration source region 16 inside gate oxide 20, so that a channel is formed below this gate electrode 23 on the surface part of semiconductor 11. In this case, the source adjoining region 17 is formed in order to suppress the substrate bias effect in this channel.

(0019)

Because in the L-IGBT 10 of a semiconductor device according to an embodiment of this

invention explained above, the distance X1 between drain adjoining region 14 and top region 15 is set to 10  $\mu\text{m}$ , the breakdown voltage between the drain and the source can be maintained without being decreased.

(0020)

In addition, because the distance X1 between drain adjoining region 14 and top region 15 is set to 10  $\mu\text{m}$ , the resistance value in the region between drain adjoining region 14 and top region 15 in extended drain region 12 can be also increased above a predetermined value. In this case, said predetermined value means the resistance value in the region between drain adjoining region 14 and top region 15 in the extended drain region 12 when the distance X1 between drain adjoining region 14 and top region 15 is 4  $\mu\text{m}$ .

(0021)

Because of that, even when a built-in diode located between the drain and source is in the breakdown status during the gate-off time period when L-IGBT 10 is used for instance for an inductance load circuit, since the resistance is increased in the region between drain adjoining region 14 and top region 15 in the extended drain region 12, the breakdown current flowing below high-concentration source region 16 will be reduced and the current amount corresponding to the reduced portion of this breakdown current will flow from the surface part of substrate 11 to the reverse part.

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(0022)

Because the breakdown current flowing below high-concentration source region 16 can be reduced in this manner, this makes it possible to suppress to a low level the voltage drop below high-concentration source region 16.

(0023)

Accordingly, since the operation of a bipolar transistor consisting of an extended drain region 12 of the second conductive type and a semiconductor substrate 11 of the first conductive type and of a high-concentration source region 11 of the second conductive type can be controlled in this manner, this makes it possible to increase the AD resistance amount.

(0024)

Figure 2 is a diagram explaining the relationship between distance X1 between drain

adjoining region 14 and top region 15 and the AD resistance amount of a semiconductor device. In this case, the AD resistance value has been set to 1 per a square area unit of a semiconductor device when  $X1 = 4 \mu\text{m}$ . As shown in Figure 2, the value of the AD resistance amount can be multiplied by a factor of 1.7 per a square area unit when compared to the case when  $X1 = 4 \mu\text{m}$  with the semiconductor device of an embodiment of this invention ( $X1 = 10 \mu\text{m}$ ).

(0025)

(Effect of the Invention)

As was explained above, since the distance corresponding to the space between the drain adjoining region and the top region can be set above  $4 \mu\text{m}$  with the semiconductor device of this invention, this makes it possible to maintain the distance without lowering the breakdown voltage between the drain and the source. In addition, because a predetermined distance is set increasing by a predetermined value the resistance value in the region between a drain adjoining region and a top region in an extended drain region with the interval between the drain adjoining region and the top region, this makes it possible to suppress to a low level the voltage drop below the high-concentration region by reducing the breakdown current flowing below the high-concentration source region even when a built-in diode located between the drain and the source reaches the breakdown status. Because of that, the AD resistance amount can be increased by controlling the operation of a bipolar transistor comprising an extended drain region of the second conductive type and a semiconductor substrate of the first conductive type, as well as a high-concentration source region of the second conductive type.

(0026)

Accordingly, when the breakdown voltage can be maintained between the drain and the source and the AD resistance amount can be increased according to this invention, this makes it possible to protect a semiconductor device from thermal failure which can be caused by excessive heat in a semiconductor device.

Brief Explanation of Figures

(Figure 1)

Figure 1 shows a profile view of a semiconductor device according to an embodiment of this invention.

(Figure 2)

Figure 2 is a diagram explaining the relationship between the drain adjoining region and the top region, and the AD resistance amount of a semiconductor device.

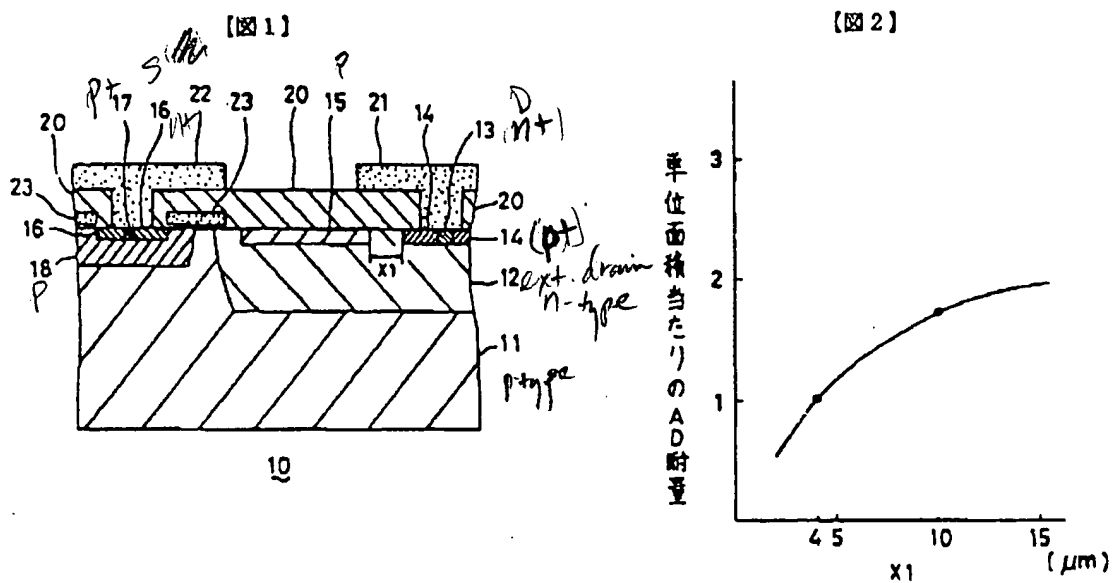
(Figure 3)

A profile view of a semiconductor device according to prior art.

(Explanation of Codes)

- 10 L-IGBT (semiconductor device)
- 11 semiconductor substrate
- 12 extended drain region
- 13 high-concentration drain region
- 14 drain adjoining region
- 15 top region
- 16 high-concentration source region

[Figure 1 and 2]



[Figure 1]

- 10 L-IGBT (semiconductor device)
- 11 semiconductor substrate
- 12 extended drain region
- 13 high-concentration drain region
- 14 drain adjoining region
- 15 top region
- 16 high-concentration source region

[Figure 2]

vertical axis AD resistance amount per square area unit

